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This table shows that suitable material can easily be obtained in winter for the demonstration of protoplasmic streaming. Of the plants studied, I should recommend Nitella and Elodea as good examples of rotation; *Gloxinia speciosa*, *Tradescantia zebrina* and *virginica*, *Abutilon striatum* (hyb.), *Lycopersicum esculentum*, *Whitlavia grandiflora*, *Cucurbita maxima*, *Lobelia Erinus*, and *Saxifraga cotyledon palmata* for circulation. *Gloxinia speciosa* is especially good, as the entire hair cell can be brought within the range of vision, and a constant change observed in the arrangement of the strands, circulation passing into rotation as the temperature rises. Campanula, Lobelia, Vinca, Streptosolen, Capsella, and Ampelopsis have markings on the cell wall which obscure the view of the protoplasm to some extent.

A complete study of the streaming involves the measurement of its rate at various temperatures from minimum through optimum to maximum. Results of such study, expressed in a graph, are available for Chara, Elodea, and Vallisneria in DAVENPORT'S *Experimental morphology* (**1**:226), and for a common Nitella in GANONG'S *Laboratory course in plant physiology* (p. 19). My own graph for Tradescantia shows a curve much flatter than that above mentioned for Nitella, though otherwise somewhat similar to it.—GRACE L. BUSHEE, *Smith College, Northampton, Mass.*

ON PLASMOLYSIS

According to the conception of plasmolysis developed by DE VRIES and PFEFFER, the contents of a cell contract and round up when it is placed in a solution whose osmotic pressure exceeds that of the cell sap. This is explained by supposing the outer layers of protoplasm to be impermeable to the substances in solution which produce the osmotic pressure. If the protoplasm is permeable to these substances, either wholly or in part, deviations from the rule given above will occur. Deviations have in fact been described by several authors and explained by supposing the protoplasm to be more or less permeable to the substances in solution, which enter the cell sap and increase its osmotic pressure.

I propose in this paper to describe deviations which range from those which are very slight to those which are of extraordinary intensity, the explanation of whose nature is entirely different from the one mentioned above.

My attention was first called to these deviations some three years ago by the results of some of my experiments on the rôle of osmotic pressure[1]

[1] A brief account of these investigations appeared in Univ. Calif. Publ. Bot. **2**:227, 229. 1906.

in marine plants. I then experimented on fresh-water plants and found even more striking results.

In order to make clear the nature of these results I will describe an experiment with Vaucheria. Zoospores which had attached themselves to slides were allowed to germinate and produce short tubes. The slides were then transferred to 0.0937 *m* NaCl solution. In the course of a few minutes the protoplasm began to contract away from the cell wall. The solution was apparently strong enough to produce plasmolysis and I prepared weaker ones. These, however, produced the same effect, taking more time to do so in proportion as they were weaker. It then occurred to me that the effect was not due to osmotic pressure but to a *contraction of the protoplasm due to the chemical action of the salt.*

In order to test this idea I endeavored to determine how dilute the solution could be made and still produce this effect. I found that even 0.0001 *m* solution produced it, though usually only after a day or so. The experiments are repeated several times with Kahlbaum's C. P. sodium chloride which I had recrystallized six times. The result remained the same.[2]

I then tried to do away with this effect. This is easily accomplished by adding a little $CaCl_2$. The addition of $CaCl_2$ in solid form increases the osmotic pressure of the solution, but in spite of this it prevents the contraction of the protoplasm away from the cell wall. If one molecule of $CaCl_2$ is present for every hundred molecules of NaCl, the algae endure solutions of 0.1 *m* (that is to say, solutions with a thousand times greater osmotic pressure) without any contraction or apparent plasmolysis.

I have since experimented with a great variety of salts and combinations of salts which produce effects similar to those just described. I have found that all the plants with which I have experimented (algae, fungi, mosses, liverworts, Equisetum, flowering plants) give similar results, though most of them are much less sensitive than Vaucheria.

After these experiments I was in no way surprised when I found that water distilled from a metal still could produce apparent plasmolysis within a few minutes, and that this could be prevented by the addition of various substances.

In what way is the contraction just described distinguishable from true plasmolysis? In many cases it cannot be so distinguished at all[3] by its appearance, but only by comparison with other (especially non-toxic or balanced) solutions, or by determination of the freezing-point of the cell sap. The protoplasm rounds up just as in true plasmolysis, and may even subsequently recover and expand in characteristic fashion when transferred to distilled water.

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[2] Vaucheria from other localities and especially in later stages proved less sensitive to the action of NaCl. Cf. Jour. Biol. Chem. **1**:363. 1906.

[3] It is possible that the results described by DUGGAR (Trans. St. Louis Acad. Sci. **16**:473. 1906, and TAKEUCHI (Bull. Coll. Agri. Imp. Tokyo Univ. **7**:623. 1908) are explicable on this basis.

It may happen that a contraction is caused by true plasmolysis, but the subsequent chemical action of the salt renders the protoplasm unable to recover and expand when the cell is transferred to distilled water. Such recovery cannot therefore be used as a means of distinguishing true plasmolysis from a contraction due to chemical action.[4] In some cases the contraction may be distinguished from true plasmolysis by the irregular outline of the contracted protoplasm.

On looking over the literature it becomes evident that such precautions as are necessary to distinguish this contraction from true plasmolysis have not been generally observed in making plasmolytic determinations, and a revision of such determinations is necessary. Determination of the freezing-point of the cell sap will certainly be needed in many cases if an accurate result is desired.

In conclusion I would call attention to the importance of this discovery in respect to one of the most prominent biological problems, the question whether salts are able to penetrate the protoplasm or not. Far-reaching conclusions have been drawn from the fact that when a cell is placed in a solution of a certain substance the protoplasm contracts and does not subsequently expand if left in contact with the solution. This has been interpreted to mean that the substance in solution is unable to penetrate the protoplasm. I find, however, in many cases, that the true interpretation is exactly the opposite. The permanent contraction of the protoplasm is caused by the *penetration of the substance in question* which produces chemical effects upon the protoplasm, wholly different from those produced by a substance whose action is purely osmotic.

In view of this we cannot give credence to certain very important conclusions and theoretical considerations which have been based on this criterion of penetrability. These points will receive fuller discussion in a subsequent paper.—W. J. V. OSTERHOUT, *University of California.*

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[4] The expression chemical action is here used in a very broad sense to include effects which are not osmotic in character.